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The Working Paper presents a work in progress.
The authors would welcome all comments and feedback on the current state of the research presented here.

Learning Before and After the Global Crisis: Firm-level Innovation in Latin America

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Abstract

Economic shocks of the kind we recently witnessed with the 2008 global financial and economic crisis do not come around very often but when they do, their effect can be catastrophic, not the least because of their impact on businesses. Existing theories of how firms react to crises such as these are ambiguous and very little empirical evidence exist, particularly for the developing world. As such, our main contribution to the literature is to shed light on these issues, articulating a theoretical framework and testing it using three waves of cross-country innovation identifying survey implemented by the World Bank in Latin American economies. The three waves coincide with a timespan that covers before, during, and after the global crises. Our results provide strong support that firms alter their practices and witness different profit outcomes before and after a downturn deending on innovation decisions. In fact, we find evidence that indicates that the profitability gains from new products for firms may be higher during downturns.

Keywords: Economic crisis, Innovation, Latin America, Productivity.
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1 Introduction

The theoretical literature on 'opportunity cost' has long argued that economic downturn provides opportunities for agents to learn and pursue knowledge, hence contributing to higher value-added innovation (see for example, Aghion and Saint-Paul, 1998, Blackburn and Galindev, 2003). Nonetheless, very limited empirical evidence exist to support these theories. In fact, there is only a small analytical literature that examines what happens to an economy during recessionary periods from the perspective of firms, a key agent in the production processes (Paunov, 2012). Although studies such as Wälde and Woitek (2004, on G7 economies) and Lee (2016, on Korea) have assessed the effects of business-cycle and demand-side shocks on within-firm activities, how these impact firm-level profitability and innovation activities, particularly the interaction between product and process innovation, is not well understood. Moreover, Flach and Irlacher (2018) argue that firms may decide to expand their product range or to lower production costs, and the net effect in terms of returns to innovation is unclear a priori.

Our main contribution to the literature is to theoretically and empirically examine if the profitability of firm-level innovation differ between economic upturn and downturn. We utilize a dataset on firms constructed using three waves of cross-country information on innovation, profitability and firm characteristics which coincide with a timespan that covers before, during, and after the most recent global financial crises. We focus on Latin American countries because, despite the obvious heterogeneity among Latin America countries, the region presents a unique opportunity to study the effect of the crises on innovation for many reasons. The global crisis had a quick and significant impact on Latin America and the Caribbean. The region's GDP fell by 1.9% in 2009 following a 4.3% positive growth rate in 2008. According to data from the International Monetary Fund, credit tightening across the region as well as demand uncertainties contributed to an estimated fall in fixed investments by 13.6% in 2009.

Nevertheless, compared to recent crises in the region, most Latin American countries weathered the recent recession quite well, at least on the macroeconomic level. In particular, the region did not experience the large-scale banking or balance of payments crises evident in past recessions(Chudik & Fratzscher, 2011). Furthermore, as pointed out by Alvarez and De Gregorio (2014), the impact of the crisis on the region was almost exclusively isolated in its influence on external and domestic demand. Notwithstanding, many structural challenges related to sluggish productivity growth were revealed as potential challenges should another shock occur in the short to medium term (Pages, 2010). As such, shedding light on the relationship between innovation profitability at different economic phases provides a much needed precursor to the design of growth stimulating policies in the region.

This paper isconnected to the relatively small body of literature that asses the impact of financial and banking crises on firm activities (Archibugi et al. (2013a, b); Kroszner et al. (2007)), and firm responses (Basseto et al (2015); Fort et al (2013); Foster et al. (2016)). We specifically examine innovation decisions and outcomes and so, our paper is also connected to the literature assessing firm level drivers of innovation [for examples, see Alvarez et al. (2015); Crespi et al. (2016); Hall (2011)]. Moreover, our paper is connected to the large literature in international economics building on models with firm heterogeneity such as Melitz (2003) which analyzes both theoretically and empirically innovation behavior at the firm level. In this vein, Bernard & Okubo (2016) analyze changes in product adding and dropping by firms over the business cycle. They find very high rates of product adding and dropping by continuing firms between the last year of the recession and the first year of the subsequent expansion.

We extend these literature as follows. First, we extend these literature as follows. First, we derive a theoretical foundation to underpin the analytical relationship betwen inovation and profitability over the business cycle and so allow for the empirical evidence on firms' innovation to be understood in the context of theory. Second, the unique dataset we build allows us to compare the experience of individual firms before and a sufficiently distant period after the global crises, allowing for materialisation of any innovation benefits.[1]

Even though there has been a number of firm-level studies that have examined firm-level innovation during crises, they are based on cross-section data and do not allow the same firm to be observed in periods of upturn and downturn (Archibugi et al., 2013a). This is partly due to the nature of innovation surveys, which solicits information on innovation activity up to three years prior and rarely re-sampled (Hall, 2011). We know that innovation is risky and firm-specific, yet a firm's effectiveness in bringing it to fruition is often inadequately monitored. Moreover, unobserved firm heterogeneity has been shown to be highly consequential in other strands of the literature, particularly as it relates to firm performance (De Loecker, 2011; Eckel & Neary, 2010; Goldberg et al., 2010; Morris, 2018; Timoshenko, 2015). Thus, monitoring the same firm before and after a crisis may provide useful information on their innovation behaviors.

Our results show that the sample of firms studied are innovation-efficient enough to benefit from innovation cost reductions due to knowledge stock growth. This results in a distinct difference in profitability outcome between the downturn period and the recovery period. When firms experienced declining external demand towards the tipping point of the crisis, we observe a robust positive and statistically significant association between innovation and profitability. On the contrary, after the tipping point of the crisis and as the economy gradually moves upward in an expansionary phase, this association is much smaller in magnitude and loses statistical significance. These results are robust to the inclusion of country and industry fixed effects, as well as addition of new variables and sample restriction.

This contrasting set of results lends empirical support to our theory that the profitability of firms from product innovation can actually be larger during the contractionary phase/economic downturn. Indeed, given that the influence of labour productivity (sales/employee) remains positive and significant irrespective of the two periods, the contrast in the two sets of estimates shows the presence of the "crisis-period learning" effect among Latin American firms. This implies that the net marginal benefit gained by the Latin American firms from engaging in innovation during the downturn period outweighed the benefits obtained from its usual sales and production activities, which is reflected in the strong profitability-product innovation nexus observed.

2 Theoretical Framework

The theoretical framework developed belongs to the "representative agent" class of models, in which there are a continuum of infinitely-lived individuals. While individuals are identical in their preferences in consumption (which is in terms of a composite basket of differentiated varieties) and time allocation, they differ in terms of the varieties produced by the firms. In other words, firms are heterogeneous. For convenience, we assume that the continuum of firms and individuals are both indexed by $j \in [0, J]$, hence implicitly specifying that each individual owns a firm in the

[1] see Jovanovic & Lach, 1997) which shows tha new products takes years to penetrate the market significantly.

economy.[2] In similar fashion to Blackburn and Galindev (2003), Blackburn and Varvarigos (2008), and Galindev (2008), technological process in the economy occurs through both external and internal learning. The former arises due to individuals' choice in allocating time to pursue knowledge, whereas the latter arises not only via learning-by-doing (Martin & Rogers, 1997, 2000) but also due to individual firm's deliberate choice in pursuing product and process innovation. In addition, firms' innovation choice and hence expected profitability, are influenced by stochastic fluctuations due to preference shocks, which is in consistent with the Latin American experience of a demand-side shock during the global crisis. In comparison to existing literature, the demand-side shock and external-learning features are similar to the 'opportunity cost' models such as Aghion and Saint-Paul (1998), Saint-Paul (1993), and the aforementioned papers on external- and internal-learning. However, instead of merely treating production activities as internal learning, our novel theoretical contribution is that, internal learning takes place through the heterogeneous firms' choices in product and process innovation, the costs of which are influenced by the outcome of the non-deliberation actions from external learning (a feature consistent with studies such as Freeman et al., 1999; Wälde, 2005).

2.1 The Model

The output produced in each period t, Y_t, consists of a continuum basket of differentiated goods in $[0, M_t]$, where M_t is the aggregate variety available. Let q_i denotes the quantity of variety i, this relationship is represented by

$$Y_t = \left\{ \int_0^{M_t} [q_{i,t}]^{(\theta-1)/\theta} di \right\}^{\theta/(\theta-1)}, \tag{1}$$

where $\theta > 1$ is the elasticity of substitution across the different varieties. Given price-taking consumers, to produce this level of output in each period t, the implied demand function for each variety is then $q_{i,t} = p_{i,t}^{-\theta} P_t^{\theta-1} Y_t$, where the aggregate price index is defined by $P_t = \left\{ \int_0^{M_t} (p_{i,t})^{1-\theta} di \right\}^{1/(1-\theta)}$, implying that $P_t Y_t = \int_0^{M_t} p_{i,t} q_{i,t} di$.

Following the set-up of models with multi-product variety firms, such as Brambilla (2009), Brambilla et al. (2009), and Bernard et al. (2010), production is being served by a continuum of firms indexed by $j \in [0, J]$, where each firm j produces m_t^j of product varieties. The aggregate measure of varieties M_t therefore satisfies $M_t = \int_0^J m_t^j dj$. For analytical simplicity, we normalize $J = 1$, and assume the entry and exit flows of firms exactly cancel out in each period. For each firm j producing variety i, the production involves using labor hours, $l_{i,t}^j$, and benefits from a firm's knowledge capital stock that is common to the production of all varieties, Z_t^j, $q_{i,t}^j = q(l_{i,t}^j) Z_t^j$. In other words, firm-level knowledge capital stock exerts an Arrow-Romer type of externality to individual variety's production, and is therefore taken as given at product-level optimization for a specific variety i. For simplicity, the production function is specified as $q_{i,t}^j = l_{i,t}^j Z_t^j$.

[2]As such, we abbreviate from examining the various issues, such as job creation and destruction, labor productivity fluctuations, that arise from firms' endogenous entry and exit. These are examined in studies such as Baily et al. (2001), Bilbiie et al. (2012), and Haltiwanger (2012).

The cost function for each variety i produced by firm j is represented by

$$C^j_{i,t}(q^j_{i,t}) = F^j_{i,t} + c^j_{i,t} q^j_{i,t}, \tag{2}$$

where $F^j_{i,t}$ is the fixed cost and $c^j_{i,t}$ is the marginal cost of production. Note that, in practice, the fixed and variable costs are not necessarily the same for different varieties produced by the same firm. To model this, we introduce a combination of deterministic and stochastic components to both fixed and variable costs. Specifically, in the beginning of each period t, firms learn their cost structure, with each firm j represented by a pair of expected fixed and variable costs (F^j_0, c^j_0) drawn from a distribution $\Upsilon(\cdot)$ common to all firms. The actual costs are realized at the end of period t. These therefore mean that the actual cost-pairing for each variety, $F^j_{i,t}$ and $c^j_{i,t}$, are stochastic functions of (F^j_0, c^j_0), where the production costs of the different varieties are drawn from distributions $\Upsilon_1(F^j_{i,t}|F^j_0)$ and $\Upsilon_2(c^j_{i,t}|c^j_0)$.

In addition to this stochastic process, for each variety i in each period t, each firm also spends an additional fixed cost, $\phi(g^{z,j}_t)$, to improve its operational efficiency, where ϕ is a decreasing function with respect to the the growth rate of knowledge capital, $g^{z,j}_t = Z^j_{t+1}/Z^j_t$. Specifically, $\partial\phi/\partial g^{z,j}_t < 0$. This feature is consistent with the specifications in studies such as Oikawa (2010). Process innovation is modelled by a two-state stationary Markov process, in which a successful process innovation (given by probability, $pr^j_{process}$) would yield a fixed cost $F^j_{L,t}$ at the end of the period, while $F^j_{H,t}$ is realized if failed. For simplicity, this particular fixed cost component and the associated probability of success is assumed to be common across all varieties. As such, we know that a firm j producing variety i will engage in process innovation if and only if $pr^j_{process}[F^j_{L,t} + \phi(g^{z,j}_t)] \geq (1 - pr^j_{process})[F^j_{H,t} + \phi(g^{z,j}_t)]$, which yields a threshold probability above which firms will engage in process innovation:

$$pr^C_{process} = \frac{F^j_{H,t} + \phi(g^{z,j}_t)}{2\phi(g^{z,j}_t) + F^j_{H,t} + F^j_{L,t}}. \tag{3}$$

Given these, before the realization of fixed cost at the end of period t, we know that the expected fixed cost incurred by firm j in producing variety i is given by

$$\mathbb{E}_t(F^j_{i,t}) = F^j_0 + pr^j_{process} F^j_{L,t} + (1 - pr^j_{process}) F^j_{H,t} + \phi(g^{z,j}_t). \tag{4}$$

Similarly, in addition to the random component drawn from $\Upsilon_2(c^j_{i,t}|c^j_0)$, in the beginning of period t, for the variable cost each firm j also spends an additional $\gamma(g^{z,j}_t)$ per quantity of variety i to investigate how many varieties to introduce based on their production efficiency parameters. The R&D cost is also assumed to be a decreasing function of knowledge stock growth, $\partial\gamma/\partial g^{z,j}_t < 0$. Following Brambilla (2009) and Lim (2018), the number of varieties introduced by each firm is assumed to be small relative to the aggregate number of varieties, M_t, so that the effect of a single firm on aggregate price index and variety is negligible.[3]

Taking the optimized marginal cost as given, firms choose the price of a variety i that maximizes variable profits given by $p^j_{i,t} - c^j_{i,t}q^j_{i,t}(p^j_{i,t})$. Given CES functional form in (1), we have a constant price mark-up $p^j_{i,t} = \frac{\theta}{\theta-1}c^j_{i,t}$, with indirect profits given by $\pi^j_{i,t} = \Theta(c^j_{i,t})^{1-\theta}(P_t)^{\theta-1}Y_t - \mathbb{E}_t(F^j_{i,t})$, or equivalently,

$$\pi^j_{i,t} = \Theta(c^j_{i,t})^{1-\theta}(P_t)^{\theta-1}Y_t - F^j_0 - pr^j_{process}F^j_{L,t} - (1 - pr^j_{process})F^j_{H,t} - \phi(g^{z,j}_t), \quad (5)$$

where $\Theta = (\theta - 1)^{\theta-1}/\theta^\theta$.

Given this profits function, in each period t, the firm investigates on whether to introduce a specific variety i. Specifically, firm j decides whether to engage in product innovation if, for a specific variety i,

$$\Pr(\pi^j_{i,t} \geq 0|F^j_{i,t}, c^j_{i,t})E(\pi^j_{i,t}|\pi^j_{i,t} \geq 0; F^j_{i,t}, c^j_{i,t}) \geq 0,$$

where the decision to engage in product innovation is conditional on the decision of engaging in process innovation. For simplicity, we assume that this additional variable cost is incurred only after a successful product innovation, and a firm does not bear this cost in the event the specific variety i is not introduced. By assuming a two-state stationary Markov process again, for a success probability $pr^{i,j}_{product}$, the expected profits function for a specific variety i is given by

$$\begin{aligned}\mathbb{E}_t(\pi^j_{i,t}) = &\left\{pr^{i,j}_{product}\Theta([c^j_0 + \gamma(g^{z,j}_t)])^{1-\theta}(P_t)^{\theta-1}Y_t\right\} \\ &- F^j_0 - pr^j_{process}F^j_{L,t} - (1 - pr^j_{process})F^j_{H,t} - \phi(g^{z,j}_t).\end{aligned} \quad (6)$$

A firm j chooses to introduce a new variety if and only if $\mathbb{E}_t(\pi^j_{i,t}) \geq 0$. In the margin, we can derive a threshold probability level, $pr^C_{product}$, above which the firm will engage in product innovation:

$$pr^C_{product} = \frac{F^j_0 + pr^j_{process}F^j_{L,t} + (1 - pr^j_{process})F^j_{H,t} + \phi(g^{z,j}_t)}{\Theta([c^j_0 + \gamma(g^{z,j}_t)])^{1-\theta}(P_t)^{\theta-1}Y_t}. \quad (7)$$

From (7), it is straightforward to derive
$\partial(pr^C_{product})/\partial(pr_{process}) = \{\Theta([c^j_0 + \gamma(g^{z,j}_t)])^{1-\theta}(P_t)^{\theta-1}Y_t\}^{-1}(F^j_{L,t} - F^j_{H,t}) < 0.$

Proposition 1: *The threshold probability of product innovation (above which firms would engage in innovation) is lower, the higher the success probability of process innovation of a firm.*

In other words, **Proposition 1** states that, a typical firm would be more willing to engage in product innovation if it has implemented a successful process innovation. This positive relationship between product and process innovation is independent of

[3] Similar to their studies, we also abbreviate from strategic pricing considerations across varieties produced by the same firms.

the business cycle and therefore should remain robust both before and after a crisis.

Next, we turn to the household's intertemporal optimization problem. Suppose, there is a continuum of identical infinitely-lived individuals, each owning a firm along the continuum $j \in [0, J]$, derives utility from consumption and leisure (which is determined from the time allocated to production and learning). Given that individuals are homogenous, we subsume the superscript and write the lifetime expected utility function of a typical individual as

$$U_t = \mathbb{E}_t \sum_{t=0}^{\infty} (1+\Lambda)^{-t} \left[A_t^U \ln C_t + \omega \ln(1 - l_t - h_t) \right], \tag{8}$$

where $\mathbb{E}_t$ is the expectation operator, C_t is total consumption, $\Lambda \in (0, 1)$ is the discount factor, ω is preference parameter for leisure, and A_t^U denotes a positively-valued stochastic preference parameter, assumed to be bounded, independent and identically distributed, and follows a stationary process with mean A_0^U and constant variance σ^2.

Given the model specifications, equating production and consumption would necessarily mean $P_t C_t = P_t Y_t = \int_0^{M_t} p_{i,t} q_{i,t} di = M_t P_{i,t} l_{i,t} Z_t^j$, or equivalently, in a symmetric equilibrium (where $l_{i,t} = l_t$, $P_{i,t} = P_t \forall i$, $Z_t^j = Z_t \ \forall j$), we have $C_t = M_t^* l_t Z_t$. In addition, following Blackburn and Galindev (2003), for given parameters $\Gamma, \xi, \psi > 0$, the knowledge accumulation process is given by $Z_{t+1} = Z_t \Gamma h_t^{\xi} L_t^{\psi}$, where $\xi, \psi > 0$, and L_t is the aggregate employment. By imposing the terminal condition, $\lim_{T->\infty} (1+\Lambda)^{-T} \mathbb{E}_t(\lambda_{t+T} Z_{t+T+1}) = 0$, and let $\sum_{k=1}^{\infty} (1+\Lambda)^{-k} \mathbb{E}_t(A_{t+k}^U) = A_0^U/\Lambda$, solving the individuals' intertemporal optimization problem yields optimal time allocations of

$$l_t = \frac{A_t^U}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U}, \;\; h_t = \frac{\xi \frac{A_0^U}{\Lambda}}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U}. \tag{9}$$

A straightforward derivation of the partial derivatives, $\partial l_t / \partial A_t^U$ and $\partial h_t / \partial A_t^U$, yields:

$$\frac{\partial l_t}{\partial A_t^U} = \frac{\omega + \xi \frac{A_0^U}{\Lambda}}{\left(\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U\right)^2} > 0; \quad \frac{\partial h_t}{\partial A_t^U} = -\frac{\xi \frac{A_0^U}{\Lambda}}{\left(\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U\right)^2} < 0, \tag{10}$$

which suggests that labor supply for production tend to be pro-cyclical while time allocated to learning is counter-cyclical. In other words, during crisis period, agents work less and allocate more time to learning and accumulating knowledge, whereas during upswing, agents supplies more labor for production and invest less in learning: a result that is consistent with relevant studies in the theoretical literature on "external versus internal learning" (Blackburn & Galindev, 2003; Galindev, 2008).

Further, by further also assuming symmetric equilibrium in the labor market, $l_t = L_t$, we can derive the growth rate of knowledge stock with optimal time allocation:

$$g_t^{z,j} = \frac{Z_{t+1}}{Z_t} = \Gamma \left(\frac{\xi \frac{A_0^U}{\Lambda}}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U} \right)^{\xi} \left(\frac{A_t^U}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U} \right)^{\psi}. \tag{11}$$

Lastly, subsuming superscripts i and j for ease of readability, from (6) we can write the expected profits function of a typical firm producing a new variety as

$$\pi_t = \left\{pr_{product}\Theta([c_0 + \gamma(g_t^{z,j})])^{1-\theta}(P_t)^{\theta-1}M_t l_t Z_t\right\}$$
$$- F_0 - pr_{process}F_{L,t} - (1 - pr_{process})F_{H,t} - \phi(g_t^{z,j}),$$

which when differentiated with respect to A_t^U, yields

$$\frac{\partial \pi_t}{\partial A_t^U} = \frac{R_t(\omega + \xi\frac{A_0^U}{\Lambda})}{l_t\left(\omega + \xi\frac{A_0^U}{\Lambda} + A_t^U\right)^2} + \frac{\partial g_t^{z,j}}{\partial A_t^U}\left\{\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0 + \gamma(g_t^{z,j})]} - \phi'(\cdot)\right\}, \tag{12}$$

where $R_t = pr_{product}\Theta([c_0 + \gamma(g_t^{z,j})])^{1-\theta}(P_t)^{\theta-1}M_t l_t Z_t$. The sign of $\partial\pi_t/\partial A_t^U$ is ambiguous, but the following can be derived:

Proposition 2: *The relationship between expected profits and product innovation of a typical firm is anti-cyclical to preference shock if conditions (i) and (ii) below hold:*

(i) $\frac{\partial g_t^{z,j}}{\partial A_t^U}\left\{\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0+\gamma(g_t^{z,j})]} - \phi'(\cdot)\right\} > \frac{R_t}{l_t}(\omega + \xi\frac{A_0^U}{\Lambda})\left(\omega + \xi\frac{A_0^U}{\Lambda} + A_t^U\right)^{-2}$; **and**

(ii) $\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0+\gamma(g_t^{z,j})]} - \phi'(\cdot) < 0,\ \frac{h_t}{l_t} > \frac{\xi^2 A_0^U}{\Lambda\psi}(\omega + \xi\frac{A_0^U}{\Lambda})^{-1}$,

or $\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0+\gamma(g_t^{z,j})]} - \phi'(\cdot) > 0$**,** $\frac{h_t}{l_t} < \frac{\xi^2 A_0^U}{\Lambda\psi}(\omega + \xi\frac{A_0^U}{\Lambda})^{-1}$.

In other words, during period of negative preference shock, more product innovation activities result in higher expected profits, if the analytical conditions hold.

Proposition 2 provides a hypothesis that not only accounts for the "*learning during crisis*" feature of the 'opportunity cost' theoretical literature discussed, but also a more firm-specific innovation and profitability-based explanations than studies such as Francois and Lloyd-Ellis (2003) and Malley and Muscatelli (1999). The economic intuition is that, while product innovation generally results in higher firm profits, it is possible that the profits gained from product innovation by firms is higher during a contractionary phase than during an upturn. This happens when the net marginal benefits (in terms of within-firm knowledge growth) gained resulting from a successful innovation during the "crisis-period learning" is greater than the within-firm productivity gain from usual production activities [condition (i)], and if the optimal within-firm resource allocation condition is satisfied [condition (ii) essentially states that, if the net cost reduction gained from knowledge stock growth associated with product innovation is greater than process innovation, then the within-firm external-to-internal learning ratio (h_t/l_t) ought to be higher, vise versa].

3 Empirical Strategy

Based on the two propositions derived, we formulate our empirical strategy. Specifically, the set-up of an empirically testable form that jointly tests for the two propositions is given by:

$$
\begin{aligned}
PdctInnov_{c,jt} = \alpha_0 + \alpha_1 PcessInnov_{c,jt} + \alpha_2 Z_{c,jt-1} \\
+ \sum_{l=1}^{L} \psi_{l,c} X_{l,c,jt} + \sum_{m=1}^{n-1} \lambda_{m,c} \Xi_{m,c,jt} + \mu_j + \varepsilon_{c,jt},
\end{aligned} \tag{13}
$$

$$
\begin{aligned}
\pi_{c,jt} = \beta_0 + \beta_1 PdctInnov_{c,jt} \\
+ \sum_{k=1}^{K} \psi_k \Upsilon_{k,c,jt} + \sum_{m=1}^{n-1} \lambda_m \Xi_{m,c,jt} + \mu_j + v_{c,jt}.
\end{aligned} \tag{14}
$$

where $j(t)$ is a firm (time) index; $c = 1, 2$ denotes the 2004-10, 2011-17 period; $PdctInnov_{c,jt}$ and $PcessInnov_{c,jt}$ are indicators of product and process innovation; $\pi_{c,jt}$ the profits; $Z_{c,jt-1}$ a proxy variable serving as a "catch-all" representation of firm's innovation efficiency (to be elaborated further). $\{\Xi_{m,jt}\}_{m=1}^{n-1}$ refers to a set of $n-1$ firm characteristic variables (with firm's size being the excluded characteristic for exclusion restriction). $\{X_{l,jt}\}_{l=1}^{L}$ and $\{\Upsilon_{k,jt}\}_{k=1}^{K}$ denote the set of control variables for the equations corresponding to (13) and (14) respectively. Lastly, μ_j captures time-invariant firm-specific fixed effect that accounts for firm heterogeneity, whereas $\varepsilon_{c,jt}$ and $v_{c,jt}$ are the error terms.

By assuming that firms' voluntary reporting of product and process innovation represent revealed preferences of the actual within-firm success probability, (13) provides an empirically testable equation for Proposition 1. Likewise, by jointly estimating (13) and (14), with the inclusion of the "catch-all" term for firm's innovation efficiency, $Z_{c,jt}$, in (13), we fully account for the fact that, in Proposition 2, the effect of a preference shock on the nexus between expected profits and product innovation is conditional on whether the "*costs associated with product and process innovation are independent of its knowledge stock growth*". Although knowledge stock is not directly observable, and the product and process innovation costs are not reported in the survey, this theoretical element refers to whether innovation activities benefit from within-firm knowledge accumulation, therefore essentially reflects the efficiency of a firm's innovation capacity. Firms with efficient innovation capacity will experience cost reduction to innovation as knowledge accumulates; those without will not. A reasonable empirical instrument is therefore to include the "catch-all" predicted values from a R&D participation or input equation obtained from a standard Heckman selection equation, fitted by

$$
\hat{Z}_{c,jt-1} = \Pr(RD_{c,jt-1} = 1 | \, \mathbf{z}_{b,c,jt-1}] = \Phi(\sum_{b=1}^{B} \mathbf{z}_{b,c,jt-1} Z_{b,c,j}), \tag{15}
$$

where $\{\mathbf{z}_{b,c,jt-1}\}_{b=1}^{B}$ is the set of explanatory factors in the selection equation, $RD_{c,jt-1}$ indicates R&D engagement made by firm j in period $t-1$, $\Phi(\cdot)$ is the cumulative density function of the normal distribution. If the predicted innovation effort, $\hat{Z}_{c,jt-1}$, is positive and statistically significant, then we can infer that a firm is innovation efficient enough to benefit from product and process innovation cost reduction, associated with the declining function of within-firm knowledge capital growth.

In relation to the theory, our main coefficients of interest are α_1, α_2, and β_1. For Proposition 1 to have empirical support, the estimated coefficients for α_1 need to be consistently positive and statistically significant, irrespective of whether it is before or after the crisis. On Proposition 2, again, irrespective of the business-cycle phase, the results associated with the coefficient α_2 would inform us on whether firms in the region are innovation-efficient enough to benefit from cost reduction associated with knowledge stock growth. For the more generalized form of Proposition 2 to be valid, the estimated coefficients of α_2 ought to be positive and statistically significant. If there is empirical support for the feedback to innovation cost reduction within firms, then the estimated coefficients of β_1 between the two different phases of business cycle should be consistently different across various robustness test.

4 Data

We use firm-level data from the World Bank Enterprise surveys (WBES). WBES data is available for over 130,000 firms in 135 countries.[4] As shown in Table A.1, we focus on 1,836 firms across seven of these countries (Argentina, Bolivia, El Salvador, Honduras, Nicaragua, Peru & Uruguay) because firms from these countries were interviewed before, during and after the crises years, hence, enabling the formation of a balanced panel with three time periods.

These firms are from 27 manufacturing industries and 8 services industries. The surveyed unit is the main production facility of a firm. The data include accounting information on sales, inputs, labor, stock of capital, investment and several other expenditures; and broader information such as ownership structure, characteristics of the labor force, relations with competitors, clients and suppliers, innovation, and market environment and investment climate.

4.1 Measurement of Variables

For this study, innovation output is represented by two dichotomous variables illustrating product and process innovation. Product innovation is one if the manager of a particular firm self-reported that the firm has undertaken a product innovation in the past three fiscal years. Similarly, process innovation is one if the manager reported that the firm undertook a process innovation in the last three fiscal years. These two variables are innovation output variables and thus, consistent with OECD (2005). We attempt to evaluate innovation input and develop a binary variable that assumes the value of one if the firm invested in R&D in the last three fiscal years. This approach gives us a good basis to evaluate if there is a heterogeneous effect of specific variables on measures of both innovation input and output. In addition, given the revealed preference nature of self-reporting surveys, the voluntary reporting of an innovation activity by a firm manager would likely indicate a successful innovation that has been undertaken by firm. The use of the indicators of product and process innovation in evaluating Proposition 1 is therefore justifiable.

[4] The World Bank has been conducting these surveys since 2000 for the manufacturing and services sectors in every region of the world. In each country, businesses in the cities or regions of major economic activities are interviewed. The WBES surveys formal (registered) companies with five or more employees, but excludes firms that are wholly government owned. See www.enterprisesurveys.org/ for further information.

Of the 675 firms surveyed in each of the three years, 570 witnessed an innovation output (introduced either a process or product innovation) in at least one period. More precisely, 274 introduced an innovation output in only one period, 124 introduced innovation output(s) in two periods and 172 introduced an innovation output in all three years.[5] Regarding process and product innovation complementarity, of the 570 firms that witnessed an innovation output, 371 of them introduced both a product and process innovation in the same period. This suggests a high level of complementarity between these two types of innovation and thus represents a strong reason not to treat these two outputs independently.

In addition, throughout the literature various other drivers of innovations have been identified. For instance, innovation is associated with investments in machinery and equipment(Crepon et al. (1998); Mairesse et al. (2005)), investments in human capital (Crespi et al., 2016), and expenditures on training designed to enhance the absorptive capacity of the workforce (Alvarez et al., 2015). In terms of firm size, the broad consensus is that small and very large firms have the highest innovation propensities (Hall, 2011), although the sector (Cainelli, 2005) and ownership structure also matter (Zahler, 2014). We follow these studies and include a wide battery of control variables as highlighted in Table A.2.

We also include a number of control variables to exclude alternative explanations in all our estimations. First, since large firms are likely to be better performing than smaller firms, we control for firm size measured as the log of employment. Second, we capture the financial, knowledge and market obstacles that firms face in their innovation activities. In particular, we follow (Mairesse et al., 2005) and include dummy variables for the firms' managers perception of the level of financial constraints and the accessibility of credits. Third, research shows that international-oriented firms are higher performers in terms of innovation compared to firms that focus on local or domestic markets. We include a control for whether the firm is involved in the international market, use foreign technology and is a recipient of foreign direct investment (FDI). Fourth, we also control for whether the firm is part of a large group, which may allow it to draw on the resources and knowledge of other group members not available to independent firms.

Notwithstanding the benefits of the WBES, there are at least three limitations to consider. First, the WBES does not cover informal firms. If the proportion of firms in the informal sector is small, this would be innocuous but as pointed out by Crespi et al. (2016), in countries like Paraguay and Nicaragua, the informal sector accounts for an estimated 70% of total GDP. As such, we urge some caution with the interpretation of our findings since unintentionally they condition on formality.

Second, earlier WBES solicited financial data at the national currency level. We follow the World Bank methodology in converting the data to comparable across countries, despite its imperfection.[6] An alternative would be to use a measure of

[5]This is not surprising given the way innovation questions are asked in these surveys. The survey questions require that managers respond to questions on whether the firm has implemented product or process innovation activities as well as their R&D and technological involvement in the last three fiscal years. The specific questions are, *"Over the last three fiscal years: (i) Did this establishment introduce onto the market any new or significantly improved products?; (ii) Has this establishment introduced any new or significantly improved production processes including methods of supplying services and ways of delivering products?; (iii) Has the firm invested in R&D over the last three fiscal years and if yes, how much?; (iv) What is this firms annual expenditure on purchases of information technology?"*.

[6]This involves using the market exchange rates to convert all financial variables to USD and subsequently deflate these numbers to the reference year (2010) using the CPI from the Penn World Tables. Conceptually speaking, this is imperfect as the USD variables are deflated by

purchasing power parity (PPP) or the rate at which the currency of one country would have to be converted into that of another country to buy the same amount of goods and services in each country.[7] Throughout the empirical implementation we always use country fixed effects. The use of country fixed effects partly mitigates any issues caused by any persistent discrepancies between purchasing power parity and exchange rates. Furthermore, we use the WBES recommended strict weighting for all our analysis. Further, to control for outlier effects, we eliminate all firms with sales growth over 250% and firms that reported a ratio of R&D spending to sales higher than 50%. We also drop firms in industries with less than 10 observations in any given year.

Third, our measure of innovation is based on self-reported recall activity in a survey that covers many other areas of the firm's activity. Cirera & Muzi (2016) present the results of an experiment that compares self-reported innovation rates in short questionnaires like the WBES and more specific innovation surveys with follow-up innovation related questions depending on answers given. They show that a small set of questions included in a multi-topic, firm-level survey like WBES tends to overestimate innovation rates. Furthermore, the information on process and product innovation that we use is based on dummy variables instead of a continuous measure like the innovative sales share. Bertrand & Mullainathan (2001) show the likely bias when analyzing subjective data given their likely correlation with context variables. The authors conclude that while subjective variables can be used as explanatory variables or to explain behavioral differences between individual agents, models that use subjective data as dependent variables are likely to produce biased estimates.

The best remedy to these limitations is to use both subjective and objective measures of innovation and contrast empirical findings. Unfortunately, this is not possible for our analysis as no comparable objective data was sought across the sample countries in the innovation module of WBES. As such, we exploit: (i) the wide regional variation to minimize the scale of measurement errors issues; and (ii) the panel structure of the dataset to account for firm heterogeneity. Nevertheless, as mentioned, given that any voluntary reporting of firms' engagement in innovation activities is likely to reveal only the successful ones, this partly mitigates some of the limitations discussed when the measures are used in evaluating the theoretical propositions.

5 Results

To recap, we have examined firm-level innovation activities in the Latin American region. Controlling for firm, country, and industry characteristics, we consider whether there is empirical support that the behavior of the firms differed during the downturn period (as the economies gradually head towards the trench of the crisis period) and the upturn, recovery period (as the economies recover from the aftermath of the negative demand shock), in relation to the theoretical propositions discussed in Section 2. The results for (13) and (14) are summarized in Table A.3 and A.4 respectively.

the country deflator, which is local in nature. Nevertheless, given that both operations involve multiplication/division, mathematically there is no difference in terms of which operation is implemented first.

[7]See Crespi et al. (2016) for a very persuasive argument why this would not be a good idea in this case.

5.1 Main Results

In Table A.3, we observe a consistently positive estimated coefficient for α_1, significant at 1 percent level. The large positive values observed for the estimated coefficient suggest that a successful process innovation is likely to result in "cheaper cost" experienced by a firm to engage in product innovation, hence increasing the incentive to engage in product innovation. This therefore provides empirical support for Proposition 1.

With regards to coefficient α_2, irrespective of the business-cycle phase, we observe positive estimates that are at least significant at the 10 percent level for the proxy variable of $\hat{Z}_{c,jt-1}$ (Innovation Efficiency). This suggests that the sample firms are innovation-efficient enough to benefit from innovation cost reductions due to knowledge stock growth. When analyzing the results in Table 4, we therefore proceed by interpreting the generalized version of Proposition 2. Recall that the primary coefficient of interest is β_1, which refers to the elasticity of firm profitability with respect to product innovation. We observe two distinct set of estimates between the downturn period before the crisis, and the recovery period after the crisis. On one hand, when firms experienced declining external demand as the economy moved towards the tipping point of the crisis, we observe robust positive estimates for $\hat{\beta}_1$ that are statistically significant at the 1 percent level. On the other hand, after the tipping point of the crisis and as the economy gradually moves upward in an expansionary business-cycle phase, all the estimated coefficients for product innovation are of much smaller magnitude and statistically insignificant. These results are robust to the inclusion of country and industry fixed effects, as well as addition of new variables and sample restriction.

This contrasting set of results lends some empirical support to Proposition 2, as it indicates that the profitability of firms from new products can actually be larger during the contractionary phase/downturn. Indeed, given that the influence of labour productivity (sales/employee) remains positive and significant irrespective of the two periods, the contrast in the two sets of estimates for β_1 shows the presence of the "crisis-period learning" effect among Latin American firms. This implies that the net marginal benefits gained by the Latin American firms from engaging in innovation during the downturn period outweighed the benefits obtained from its usual sales and production activities, which is translated to the strong profitability-product innovation nexus observed for the downturn period.

Intuitively, as the global crisis began to unravel back in 2009 and was at its worst in the leading developed economies such as United States, it is likely that firms in the Latin American economies anticipated the impending negative demand shock, therefore allocated greater resources to external learning. The knowledge gained from the learning during the downturn period translates to more impactful process and product innovation, which in turn result in higher profitability gained. Thus, this anti-cyclical property observed with the Latin American economies is not only consistent with the 'opportunity cost' theoretical literature, but also provides empirical support to our assertion that it is more profitable for firms to introduce new products during economic downturn than upturn.

5.2 Alternative Explanations and Robustness Check

A large empirical literature using firm and plant-level data documents that, on average, exporting producers are more productive than nonexporters (Aw et al., 2011). This reflects the self-selection of more productive firms into the export market but, in some cases, may also reflect a direct effect of exporting on future productivity gains. Aw et al (2010) find that productivity evolution is endogenous, being impacted positively by both R&D investment and exporting and, when modeled as discrete activities, the impact of R&D is larger. They argue that self-selection of high productivity plants is the dominant channel driving export market participation and R&D investment and this is reinforced by the effect of each investment on future productivity.

As such, it is possible that our results are driven by exporting firms which experience above average productivity growth and thus increased profit. Our approach to controlling for productivity growth would not be able to capture this because there isn't sufficiently large gap in time between innovation outcome and productivity improvement. To examine this, we restrict our sample to non-exporters, which account for about 70% of our sample. As shown in Table A.5 and A.6, this does not significantly change the underlying arguments presented above.

Second, a growing literature shows that multinational subsidiaries generally outperform domestic firms [for example, see Guadalupe et al. (2012)]. Many have argued that this is because multinationals transfer superior technologies and organizational practices to their foreign subsidiaries. In this context, Guadalupe et al (2012) show that multinational firms acquire the most productive domestic firms, which, on acquisition, conduct more product and process innovation (simultaneously adopting new machines and organizational practices) and adopt foreign technologies, leading to higher productivity. Our baseline results above could be influenced by this because, although we control for FDI in the regressions, our empirical strategy, because of data limitations, do not explicitly account for foreign transfer of technology. To check for robustness of our results against this, we restrict the sample to only domestic firms. As shown in Table A.7 and A.8, even with this restriction our baseline results still hold.

Third, many firms around the world have sought and acquired the ISO9000 quality standard since its introduction in 1987. These standards are not specific to performance targets or the technical quality specifications of outputs but rather the management system that governs the day-to-day of the firm. Goddess and Sleuwaegen (2013) show that firms will make a strategic choice to obtain a quality certificate if they can absorb the sunk cost associated with such an acquisitions. As such, this represents a useful signal of the firms prospects and its current performance trajectory. This is more pronounced in less-developed, institutionally weak countries where ill-developed institutions are unable to support efficient market transactions.

In this context, this may influence our results shown earlier because firms with a faster growth prospect may self-select to acquire such a certification and thus bias those results. To assess this possibility, we again restrict our sample to firms that do not have this certification. As shown in Table A.9 and A.10, our results remain largely robust.

6 Conclusion

Existing theories of how firms react to major economic crises are ambiguous and very little empirical evidence exist, particularly for the developing world. We contribute to the literature by developing and then empirically testing theoretical propositions explaining the firm-level contrasting effects of innovation on profitability pre and post economic crises. For this we utilize a dataset on firms constructed using three waves of cross-country innovation-identifying survey implemented by the World Bank in Latin American economies. The three waves coincide with a timespan that covers before, during, and after the global crises and so allow us to evaluate the model-based theoretical propositions developed.

Our results show that the sample of firms in our study are innovation-efficient enough to benefit from innovation cost reductions due to knowledge stock growth. There is therefore a distinct difference in profitability outcomes between the downturn period and the recovery period. Specifically, we show that before the crisis when firms experienced declining external demand and was moving towards the tipping point of the crisis, a robust positive and statistically significant association between innovation and profitability exists. After the tipping point of the crisis and as the economy gradually moves upward in an expansionary business-cycle phase, this association is much smaller in magnitude and loses statistical significance. This contrasting set of results lends some empirical support to our propositions, which argue that: (i) the occurrence of product innovation depends positively on successful process innovation; (ii) the profitability of firms from new products can actually be larger during the contractionary phase or an economic downturn.

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Table A.1: Distribution of Firms (no.) by Country and Year

	2006	2010	2017	Total
Argentina	180	180	180	540
Bolivia	82	82	82	246
El Salvador	66	66	66	198
Honduras	28	28	28	84
Nicaragua	47	47	47	141
Peru	148	148	148	444
Uruguay	61	61	61	183
Total	612	612	612	1,836

Table A.2: Basic Summary Statistics

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
Product	(0/1) if firm introduced a process innovation	1,836	0.45	0.50	0	1
Process	(0/1) if firm introduced a product innovation	1,836	0.36	0.48	0	1
Profit	Log revenues minus cost (US$)	1,836	3.70	4.99	-3.64	17.16
Age	Age of firm (years)	1,836	30.19	21.79	1	163
Size	Log number of permanent employees	1,836	3.56	1.43	0	8.99
Investment	Log investment in fixed assets	1,836	13.41	4.36	-3.20	17.83
Subsidiary	(0/1) if the firm is a part of a larger firm	1,836	0.18	0.39	0	1
Foreign Technology	(0/1) if the firm uses foreign technology	1,836	0.07	0.26	0	1
FDI	(0/1) if firm has 10% or more of foreign ownership	1,836	0.12	0.32	0	1
Shareholding Power	% of overall shares help by largest shareholder	1,836	68.40	26.48	0	100
Managerial Experience	Managerial experience (years)	1,836	25.50	12.79	0	70
Human Capital	% of employees with at least a bachelors degree	1,836	9.32	4.68	0	40
Capital	Log value of capital (US$)	1,836	7.77	1.53	0.18	17.51
Material	Log value of material (US$)	1,836	10.93	4.12	-5.71	16.34
Labour Productivity	Log sales per worker (US$)	1,836	8.93	3.04	-0.76	15.62
Innovation Efficiency (2004 – 2006)	Predictions from a Heckman equation	612	4.64	4.12	-1.06	17.64
Innovation Efficiency (2008 – 2010)	Predictions from a Heckman equation	612	6.25	2.97	-5.69	12.76

Table A.3: Product, Process and Innovation Efficiency

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Innovation Efficiency	0.040*	0.069*	0.009*	0.042*	0.039*	0.050*	0.086*	0.019*	0.051*	0.052*
	(0.017)	(0.032)	(0.004)	(0.017)	(0.018)	(0.023)	(0.039)	(0.008)	(0.022)	(0.023)
Process	1.511***	2.598***	0.471***	1.529***	1.531***	0.661***	1.106***	0.225***	0.673***	0.690***
	(0.164)	(0.294)	(0.049)	(0.161)	(0.164)	(0.126)	(0.213)	(0.041)	(0.124)	(0.129)
Age	0.006	0.010	0.001	0.006	0.007*	-0.003	-0.005	-0.001	-0.002	-0.001
	(0.003)	(0.005)	(0.001)	(0.003)	(0.003)	(0.003)	(0.006)	(0.001)	(0.003)	(0.003)
Size	0.012	0.017	0.003	0.025	-0.084	0.103*	0.181*	0.035*	0.131**	0.006
	(0.054)	(0.101)	(0.011)	(0.051)	(0.085)	(0.049)	(0.085)	(0.016)	(0.047)	(0.091)
Investment	-0.127***	-0.222***	-0.036***	-0.133***	-0.125***	-0.007	-0.014	-0.003	-0.005	-0.010
	(0.017)	(0.031)	(0.005)	(0.017)	(0.018)	(0.018)	(0.030)	(0.006)	(0.017)	(0.018)
Subsidiary	-0.151	-0.215	-0.025		-0.148	0.537***	0.895**	0.162***		0.453**
	(0.187)	(0.352)	(0.035)		(0.189)	(0.158)	(0.273)	(0.045)		(0.161)
Foreign Technology	0.893**	1.531**	0.208***		0.897**	0.184	0.271	0.038		0.101
	(0.283)	(0.512)	(0.063)		(0.296)	(0.243)	(0.419)	(0.065)		(0.248)
FDI					-0.131					0.475*
					(0.232)					(0.241)
Shareholding Ratio					0.004					-0.001
					(0.003)					(0.002)
Managerial Experience					-0.008					-0.007
					(0.006)					(0.005)
Human Capital					-0.037					-0.029
					(0.027)					(0.028)
R-squared			0.485					0.119		
Chi-Squared	210	168		202	225	62	57		49	68
Observations	549	549	549	549	549	512	512	512	512	512

Notes: The numbers are marginal effects (at the sample mean) for the probability of investing in product innovation. Each column shows a different regression. Models 1, 4 & 5 are from a Probit regression with the main difference being the ommission of some variables in model 4 and the inclusion of new variables in Model 4. Model 2 is from a Logit regression and Model 3 is from an linear probability model with the usual consequence given a binary dependent variable. All regressions include industry and country fixed effects and robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.4: Profitability and Product Innovation

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Product	3.209***	3.195***	3.234***	3.259***	3.281***	-0.133	-0.112	-0.116	0.427	-0.279
	(0.526)	(0.527)	(0.510)	(0.526)	(0.517)	(0.764)	(0.766)	(0.763)	(0.820)	(0.744)
Capital	0.775***	0.775***	0.775***	0.773***	0.773***	0.029	0.030	0.031	0.076	0.023
	(0.123)	(0.123)	(0.123)	(0.123)	(0.124)	(0.271)	(0.271)	(0.270)	(0.265)	(0.272)
Material	-0.825***	-0.826***	-0.823***	-0.821***	-0.820***	-1.038***	-1.039***	-1.038***	-1.064***	-1.033***
	(0.063)	(0.064)	(0.063)	(0.063)	(0.063)	(0.070)	(0.070)	(0.070)	(0.071)	(0.070)
Labour Productivity	0.345***	0.345***	0.345***	0.344***	0.344***	1.125***	1.126***	1.124***	1.152***	1.117***
	(0.052)	(0.052)	(0.051)	(0.051)	(0.051)	(0.116)	(0.116)	(0.116)	(0.116)	(0.115)
R-Squared	0.613	0.614	0.612	0.612	0.611	0.644	0.644	0.644	0.640	0.645
F-Statistic	200	200	200	195	197	111	111	111	107	113
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	396	396	396	396	396	417	417	417	417	417

Notes: These are results from estimating Equation 19 using instrumental variables. We instrument product innovation using predicted values from estimating equation 18. Each column shows a different regression and correspond to changes in the instrument based on the predicted values from the regressions shown in Table A.3. All regressions include industry and country fixed effects and use the World Bank's Enterprise survey strict weighting. Robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.5: Robustness Check 1: Product, Process and Innovation Efficiency

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Innovation Efficiency	0.047*	0.080*	0.009*	0.049**	0.047*	0.054*	0.092*	0.020**	0.052*	0.056*
	(0.019)	(0.034)	(0.004)	(0.018)	(0.019)	(0.022)	(0.038)	(0.008)	(0.021)	(0.022)
Process	1.673***	2.917***	0.506***	1.702***	1.714***	0.627***	1.039***	0.213***	0.651***	0.634***
	(0.209)	(0.386)	(0.058)	(0.206)	(0.213)	(0.139)	(0.234)	(0.046)	(0.137)	(0.141)
Age	0.002	0.003	0.000	0.003	0.004	-0.004	-0.006	-0.001	-0.003	-0.003
	(0.003)	(0.006)	(0.001)	(0.003)	(0.004)	(0.003)	(0.006)	(0.001)	(0.003)	(0.004)
Size	-0.035	-0.070	-0.008	-0.006	-0.206	0.133*	0.227*	0.045*	0.152**	0.134
	(0.069)	(0.133)	(0.013)	(0.066)	(0.111)	(0.054)	(0.093)	(0.018)	(0.054)	(0.103)
Investment	-0.121***	-0.217***	-0.033***	-0.125***	-0.124***	-0.010	-0.018	-0.003	-0.008	-0.013
	(0.019)	(0.036)	(0.006)	(0.019)	(0.020)	(0.019)	(0.031)	(0.006)	(0.018)	(0.019)
Subsidiary	0.145	0.355	0.027		0.140	0.561***	0.906**	0.176***		0.484**
	(0.195)	(0.352)	(0.036)		(0.199)	(0.167)	(0.284)	(0.050)		(0.170)
Foreign Technology	1.190***	1.985***	0.277***		1.254***	0.408	0.715	0.109		0.384
	(0.314)	(0.533)	(0.074)		(0.339)	(0.353)	(0.622)	(0.092)		(0.355)
FDI					-0.165					0.700*
					(0.361)					(0.334)
Shareholding Ratio					0.004					-0.002
					(0.003)					(0.003)
Managerial Experience					-0.012					-0.005
					(0.007)					(0.005)
Human Capital					-0.063*					0.007
					(0.028)					(0.026)
R-squared			0.471					0.121		
Chi-Squared	149	119		132	165	57	52		43	56
Observations	418	418	418	418	418	439	439	439	439	439

Notes: The numbers are marginal effects (at the sample mean) for the probability of investing in product innovation. Each column shows a different regression. Models 1, 4 & 5 are from a Probit regression with the main difference being the ommission of some variables in model 4 and the inclusion of new variables in Model 4. Model 2 is from a Logit regression and Model 3 is from an linear probability model with the usual consequence given a binary dependent variable. All regressions include industry and country fixed effects and robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.6: Robustness Check 1: Profitability and Product Innovation

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Product	3.209***	3.195***	3.234***	3.259***	3.281***	-0.133	-0.112	-0.116	0.427	-0.279
	(0.526)	(0.527)	(0.510)	(0.526)	(0.517)	(0.764)	(0.766)	(0.763)	(0.820)	(0.744)
Capital	0.775***	0.775***	0.775***	0.773***	0.773***	0.029	0.030	0.031	0.076	0.023
	(0.123)	(0.123)	(0.123)	(0.123)	(0.124)	(0.271)	(0.271)	(0.270)	(0.265)	(0.272)
Material	-0.825***	-0.826***	-0.823***	-0.821***	-0.820***	-1.038***	-1.039***	-1.038***	-1.064***	-1.033***
	(0.063)	(0.064)	(0.063)	(0.063)	(0.063)	(0.070)	(0.070)	(0.070)	(0.071)	(0.070)
Labour Productivity	0.345***	0.345***	0.345***	0.344***	0.344***	1.125***	1.126***	1.124***	1.152***	1.117***
	(0.052)	(0.052)	(0.051)	(0.051)	(0.051)	(0.116)	(0.116)	(0.116)	(0.116)	(0.115)
R-Squared	0.613	0.614	0.612	0.612	0.611	0.644	0.644	0.644	0.640	0.645
F-Statistic	200	200	200	195	197	111	111	111	107	113
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	396	396	396	396	396	417	417	417	417	417

Notes: These are results from estimating Equation 19 using instrumental variables. We instrument product innovation using predicted values from estimating equation 18. Each column shows a different regression and correspond to changes in the instrument based on the predicted values from the regressions shown in Table A.3. All regressions include industry and country fixed effects and use the World Bank's Enterprise survey strict weighting. Robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.7: Robustness Check 2: Product, Process and Innovation Efficiency

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Innovation Efficiency	0.032*	0.054	0.008*	0.036*	0.032	0.061**	0.104**	0.023**	0.061**	0.061**
	(0.016)	(0.029)	(0.004)	(0.016)	(0.017)	(0.021)	(0.037)	(0.007)	(0.021)	(0.021)
Process	1.472***	2.526***	0.465***	1.510***	1.515***	0.665***	1.107***	0.229***	0.711***	0.703***
	(0.157)	(0.280)	(0.048)	(0.155)	(0.158)	(0.125)	(0.211)	(0.042)	(0.123)	(0.127)
Age	0.005	0.008	0.001	0.005	0.007	-0.001	-0.002	-0.000	-0.001	-0.000
	(0.003)	(0.005)	(0.001)	(0.003)	(0.003)	(0.003)	(0.005)	(0.001)	(0.003)	(0.003)
Size	0.021	0.038	0.006	0.036	-0.112	0.079	0.138	0.026	0.103*	0.020
	(0.055)	(0.101)	(0.012)	(0.052)	(0.080)	(0.048)	(0.082)	(0.016)	(0.047)	(0.089)
Investment	-0.123***	-0.214***	-0.035***	-0.128***	-0.123***	-0.002	-0.006	-0.001	-0.002	-0.002
	(0.016)	(0.029)	(0.005)	(0.016)	(0.017)	(0.017)	(0.029)	(0.006)	(0.017)	(0.017)
Subsidiary	-0.109	-0.153	-0.021		-0.138	0.591***	0.986***	0.177***		0.562***
	(0.188)	(0.341)	(0.038)		(0.190)	(0.168)	(0.291)	(0.047)		(0.170)
Foreign Technology	0.792**	1.414*	0.189**		0.878**	0.464	0.781	0.118		0.434
	(0.303)	(0.565)	(0.065)		(0.314)	(0.270)	(0.479)	(0.066)		(0.272)
FDI					0.000					0.000
					(.)					(.)
Shareholding Ratio					0.002					-0.002
					(0.003)					(0.002)
Managerial Experience					-0.012*					-0.012*
					(0.006)					(0.005)
Human Capital					-0.054*					-0.018
					(0.024)					(0.026)
R-squared			0.466					0.131		
Chi-Squared	197	158		201	212	68	61		55	74
Observations	535	535	535	535	535	521	521	521	521	521

Notes: The numbers are marginal effects (at the sample mean) for the probability of investing in product innovation. Each column shows a different regression. Models 1, 4 & 5 are from a Probit regression with the main difference being the ommission of some variables in model 4 and the inclusion of new variables in Model 4. Model 2 is from a Logit regression and Model 3 is from an linear probability model with the usual consequence given a binary dependent variable. All regressions include industry and country fixed effects and robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.8: Robustness Check 2: Profitability and Product Innovation

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Product	2.589***	2.593***	2.595***	2.590***	2.660***	1.052	1.066	1.032	1.329	0.903
	(0.491)	(0.493)	(0.482)	(0.491)	(0.494)	(0.764)	(0.764)	(0.762)	(0.781)	(0.759)
Capital	0.771***	0.771***	0.771***	0.772***	0.771***	0.408*	0.405*	0.411*	0.360	0.432*
	(0.100)	(0.100)	(0.100)	(0.100)	(0.100)	(0.180)	(0.180)	(0.180)	(0.184)	(0.176)
Material	-0.884***	-0.883***	-0.882***	-0.883***	-0.879***	-1.112***	-1.112***	-1.112***	-1.110***	-1.111***
	(0.058)	(0.058)	(0.057)	(0.058)	(0.058)	(0.052)	(0.052)	(0.052)	(0.052)	(0.053)
Labour Productivity	0.448***	0.448***	0.447***	0.447***	0.447***	1.292***	1.293***	1.290***	1.298***	1.287***
	(0.060)	(0.060)	(0.060)	(0.060)	(0.060)	(0.108)	(0.108)	(0.108)	(0.109)	(0.108)
R-Squared	0.651	0.651	0.651	0.651	0.649	0.656	0.656	0.657	0.651	0.658
F-Statistic	335	334	335	329	331	154	153	154	148	158
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	510	510	510	510	510	496	496	496	496	496

Notes: These are results from estimating Equation 19 using instrumental variables. We instrument product innovation using predicted values from estimating equation 18. Each column shows a different regression and correspond to changes in the instrument based on the predicted values from the regressions shown in Table A.3. All regressions include industry and country fixed effects and use the World Bank's Enterprise survey strict weighting. Robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.9: Robustness Check 2: Product, Process and Innovation Efficiency

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Innovation Efficiency	0.003	0.008	-0.000	-0.002	-0.004	0.132*	0.228**	0.042*	0.130*	0.136*
	(0.036)	(0.067)	(0.009)	(0.037)	(0.039)	(0.054)	(0.088)	(0.017)	(0.053)	(0.057)
Process	1.617***	2.683***	0.519***	1.659***	1.658***	0.492	0.886	0.117	0.464	0.544
	(0.300)	(0.527)	(0.095)	(0.293)	(0.310)	(0.304)	(0.540)	(0.081)	(0.303)	(0.302)
Age	0.013*	0.022	0.003	0.012	0.012	0.018**	0.032*	0.003**	0.016**	0.022**
	(0.006)	(0.012)	(0.002)	(0.007)	(0.007)	(0.007)	(0.013)	(0.001)	(0.006)	(0.007)
Size	-0.052	-0.073	-0.007	-0.080	0.212	-0.114	-0.209	-0.029	-0.109	0.052
	(0.100)	(0.183)	(0.024)	(0.093)	(0.222)	(0.108)	(0.192)	(0.031)	(0.101)	(0.218)
Investment	-0.143***	-0.232**	-0.035**	-0.147***	-0.169***	-0.013	-0.019	-0.001	-0.001	-0.005
	(0.042)	(0.074)	(0.012)	(0.041)	(0.048)	(0.048)	(0.084)	(0.011)	(0.048)	(0.049)
Subsidiary	-0.401	-0.673	-0.085		-0.472	0.272	0.425	0.053		0.211
	(0.355)	(0.678)	(0.084)		(0.391)	(0.306)	(0.553)	(0.079)		(0.318)
Foreign Technology	0.196	0.381	0.055		0.203	-0.287	-0.537	-0.064		-0.269
	(0.446)	(0.851)	(0.110)		(0.432)	(0.431)	(0.791)	(0.109)		(0.452)
FDI					-0.503					0.038
					(0.384)					(0.351)
Shareholding Ratio					0.013*					0.010
					(0.006)					(0.006)
Managerial Experience					0.016					-0.003
					(0.013)					(0.014)
Human Capital					0.139					0.114
					(0.109)					(0.123)
R-squared			0.439					0.067		
Chi-Squared	71	56		69	66	15	14		14	21
Observations	120	120	120	120	120	110	110	110	110	110

Notes: The numbers are marginal effects (at the sample mean) for the probability of investing in product innovation. Each column shows a different regression. Models 1, 4 & 5 are from a Probit regression with the main difference being the ommission of some variables in model 4 and the inclusion of new variables in Model 4. Model 2 is from a Logit regression and Model 3 is from an linear probability model with the usual consequence given a binary dependent variable. All regressions include industry and country fixed effects and robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Table A.10: Robustness Check 2: Profitability and Product Innovation

	Pre Downturn					Post Downturn				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 1	Model 2	Model 3	Model 4	Model 5
Product	4.283***	4.258***	4.272***	4.268***	3.798***	2.944	2.776	2.726	1.731	1.930
	(0.604)	(0.606)	(0.604)	(0.603)	(0.609)	(1.602)	(1.586)	(1.645)	(1.449)	(1.488)
Capital	0.803***	0.805***	0.799***	0.806***	0.863***	0.749***	0.759***	0.751***	0.795***	0.799***
	(0.172)	(0.173)	(0.172)	(0.172)	(0.178)	(0.156)	(0.158)	(0.156)	(0.167)	(0.166)
Material	-0.872***	-0.874***	-0.872***	-0.875***	-0.928***	-1.676***	-1.681***	-1.685***	-1.709***	-1.708***
	(0.104)	(0.105)	(0.104)	(0.104)	(0.108)	(0.076)	(0.075)	(0.077)	(0.072)	(0.074)
Labour Productivity	0.986***	0.984***	0.993***	0.983***	0.943***	1.481***	1.479***	1.461***	1.476***	1.470***
	(0.178)	(0.179)	(0.178)	(0.178)	(0.189)	(0.178)	(0.177)	(0.181)	(0.166)	(0.169)
R-Squared	0.644	0.645	0.645	0.645	0.656	0.706	0.706	0.707	0.703	0.705
F-Statistic	516	503	517	514	428	153	152	153	153	154
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	113	113	113	113	113	106	106	106	106	106

Notes: These are results from estimating Equation 19 using instrumental variables. We instrument product innovation using predicted values from estimating equation 18. Each column shows a different regression and correspond to changes in the instrument based on the predicted values from the regressions shown in Table A.3. All regressions include industry and country fixed effects and use the World Bank's Enterprise survey strict weighting. Robust standard errors are in parentheses. * Significant at 10%, ** significant at 5%, *** significant at 1%.

Online Supplementary Appendices

Technical Derivation of Proposition 2:

First, we set up the Lagrangian function for the household's intertemporal optimization problem:

$$\text{Ļ} = \mathbb{E}_t \sum_{t=0}^{\infty} (1+\Lambda)^{-t} \left[A_t^U \ln(M_t l_t Z_t) + \omega \ln(1 - l_t - h_t)\right] + \mathbb{E}_t \sum_{t=0}^{\infty} (1+\Lambda)^{-t} \lambda_t (Z_t \Gamma h_t^{\xi} L_t^{\psi} - Z_{t+1}).$$

Differentiate with respect to h_t and l_t yields the first-oder conditions:

$$\frac{\omega}{1 - l_t - h_t} = \frac{A_t^U}{l_t}, \tag{A1}$$

$$\frac{\omega}{1 - l_t - h_t} = \xi \frac{\lambda_t Z_{t+1}}{h_t}, \tag{A2}$$

$$\lambda_t Z_{t+1} = (1+\Lambda)^{-1} \mathbb{E}_t(A_{t+1}^U) + (1+\Lambda)^{-1} \mathbb{E}_t(\lambda_{t+1} Z_{t+2}). \tag{A3}$$

By imposing the terminal condition, $\lim_{T->\infty}(1+\Lambda)^{-T}\mathbb{E}_t(\lambda_{t+T} Z_{t+T+1}) = 0$, and let $\sum_{k=1}^{\infty}(1+\Lambda)^{-k}\mathbb{E}_t(A_{t+k}^U) = A_0^U/\Lambda$, combining (A1)-(A3) would yield optimal time allocations of

$$l_t = \frac{A_t^U}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U}, \;\; h_t = \frac{\xi \frac{A_0^U}{\Lambda}}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U}. \tag{A4}$$

Taking $\partial l_t / \partial A_t^U$ and $\partial h_t / \partial A_t^U$, we can derive the partial derivatives as

$$\frac{\partial l_t}{\partial A_t^U} = \frac{\omega + \xi \frac{A_0^U}{\Lambda}}{\left(\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U\right)^2} > 0; \quad \frac{\partial h_t}{\partial A_t^U} = -\frac{\xi \frac{A_0^U}{\Lambda}}{\left(\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U\right)^2} < 0,$$

which suggests that labor supply for production tend to be pro-cyclical while time allocated to learning is counter-cyclical.

Next, by also assuming symmetric equilibrium in the labor market, $l_t = L_t$, we substitute both expressions in (A4) into $Z_{t+1} = Z_t \Gamma h_t^{\xi} L_t^{\psi}$. Subsequent rearrangement of terms, we can derive the growth rate of knowledge stock with optimal time allocation as

$$g_t^{z,j} = \frac{Z_{t+1}}{Z_t} = \Gamma \left(\frac{\xi \frac{A_0^U}{\Lambda}}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U}\right)^{\xi} \left(\frac{A_t^U}{\omega + \xi \frac{A_0^U}{\Lambda} + A_t^U}\right)^{\psi}. \tag{A5}$$

Taking the partial derivative of (A5) with respect to preference, A_t^U, we get

$$\frac{\partial g_t^{z,j}}{\partial A_t^U} = \frac{\partial g_t^{z,j}}{\partial h_t}\frac{\partial h_t}{\partial A_t^U} + \frac{\partial g_t^{z,j}}{\partial l_t}\frac{\partial l_t}{\partial A_t^U} \tag{A6}$$
$$= \frac{\Gamma h_t^{\xi} L_t^{\psi}}{\left(\omega + \xi\frac{A_0^U}{\Lambda} + A_t^U\right)^2}\left[\frac{-\xi^2\frac{A_0^U}{\Lambda}}{h_t} + \frac{\psi(\omega + \xi\frac{A_0^U}{\Lambda})}{l_t}\right],$$

which is ambiguous in sign.

After that, to examine analytically the implications of external and internal-learnings on firms' innovation decisions and profitability, we write the expected profits function of a typical firm producing a typical product variety as

$$\pi_t = \left\{pr_{product}\Theta([c_0 + \gamma(g_t^{z,j})])^{1-\theta}(P_t)^{\theta-1}M_t l_t Z_t\right\} \tag{A7}$$
$$- F_0 - pr_{process}F_{L,t} - (1 - pr_{process})F_{H,t} - \phi(g_t^{z,j}),$$

where the the superscripts i and j are subsumed for ease of readability.

Differentiating (A7) with respect to A_t^U, we derive

$$\frac{\partial \pi_t}{\partial A_t^U} = \frac{R_t}{l_t}\frac{\partial l_t}{\partial A_t^U} + \frac{R_t(1-\theta)}{[c_0 + \gamma(g_t^{z,j})]}\frac{\partial \gamma}{\partial g_t^{z,j}}\frac{\partial g_t^{z,j}}{\partial A_t^U} - \frac{\partial \phi}{\partial g_t^{z,j}}\frac{\partial g_t^{z,j}}{\partial A_t^U},$$

or equivalently, after some algebraic rearrangements,

$$\frac{\partial \pi_t}{\partial A_t^U} = \frac{R_t(\omega + \xi\frac{A_0^U}{\Lambda})}{l_t\left(\omega + \xi\frac{A_0^U}{\Lambda} + A_t^U\right)^2} + \frac{\partial g_t^{z,j}}{\partial A_t^U}\left\{\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0 + \gamma(g_t^{z,j})]} - \phi'(\cdot)\right\}, \tag{A8}$$

where $R_t = pr_{product}\Theta([c_0+\gamma(g_t^{z,j})])^{1-\theta}(P_t)^{\theta-1}M_t l_t Z_t$. The first term in the expression is strictly positive. However, due to $\frac{\partial g_t^{z,j}}{\partial A_t^U}$ being ambiguous [see (A6)], and $\gamma'(\cdot), \phi'(\cdot) < 0$, the sign of the overall expression is ambiguous. It is also worth pointing out that, if the R&D and process innovation costs are independent of knowledge stock growth, $\gamma'(\cdot) = \phi'(\cdot) = 0$.

We therefore state the following propositions:

Proposition 2: *The expected profits and product innovation of a typical firm is strictly pro-cyclical to preference shock if the costs associated with product and process innovation are independent of its knowledge stock growth. However, this can also be anti-cyclical if conditions (i) and (ii) below hold:*

(i) $\frac{\partial g_t^{z,j}}{\partial A_t^U}\left\{\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0+\gamma(g_t^{z,j})]} - \phi'(\cdot)\right\} > \frac{R_t}{l_t}(\omega + \xi\frac{A_0^U}{\Lambda})\left(\omega + \xi\frac{A_0^U}{\Lambda} + A_t^U\right)^{-2}$; **and**

(ii) $\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0+\gamma(g_t^{z,j})]} - \phi'(\cdot) < 0$, $\frac{h_t}{l_t} > \frac{\xi^2 A_0^U}{\Lambda\psi}(\omega + \xi\frac{A_0^U}{\Lambda})^{-1}$,

or $\frac{R_t(1-\theta)\gamma'(\cdot)}{[c_0+\gamma(g_t^{z,j})]} - \phi'(\cdot) > 0$**,** $\frac{h_t}{l_t} < \frac{\xi^2 A_0^U}{\Lambda\psi}(\omega + \xi\frac{A_0^U}{\Lambda})^{-1}$.

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