

**Online Appendix for “The Impact of Emerging Market Competition on Innovation and Business Strategy”**

**(NOT FOR PUBLICATION)**

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## Appendix A: A Theory of Irreversible Innovation Strategy Choices, Innovation Investments and the Performance impact of Competition

In this section we develop a baseline theory of irreversible innovation strategy commitments that is directly related to the main hypotheses developed in section 2 of the main paper. The order of the hypotheses reflects the order in which they are presented in the paper.

### A.1 Model setup

This section outlines our baseline theory, which serves two purposes. First, we formalize the idea of an irreversible strategy choice that allows us to clarify what type of information the new data on strategic choices helps capture. Second, the model allows us to introduce the distinction between process and product innovations, which in turn will guide our empirical analysis.

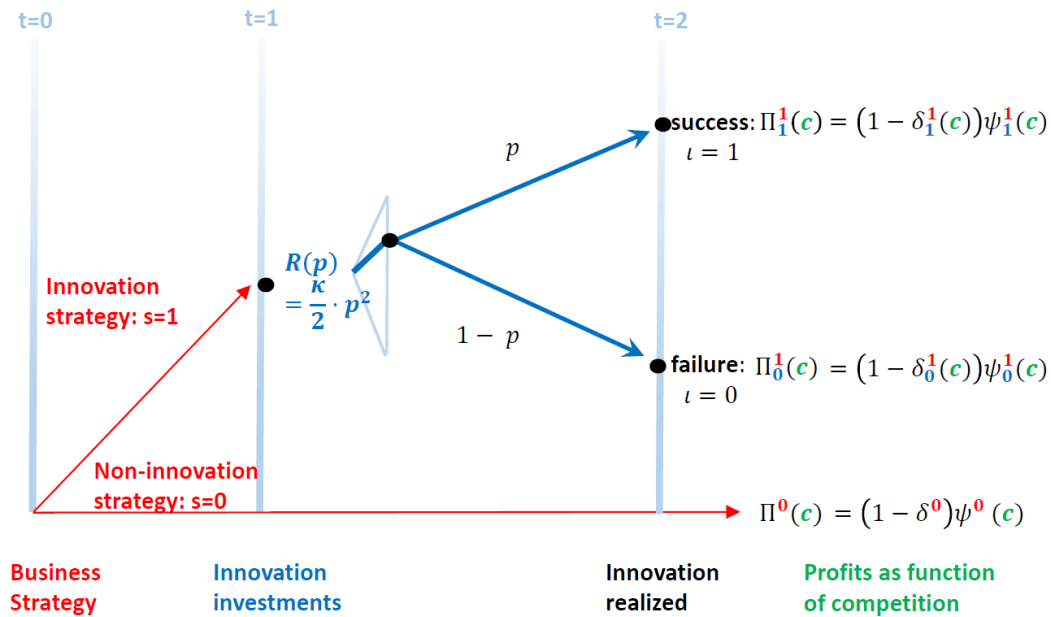


Figure 1: Timing and details of the model of strategy choice and risky innovation with

We focus on the optimal decisions for a single firm, although it is straightforward to generalize the model to a monopolistic competition industry equilibrium. Demand, production technology, and choices give rise to expected profits  $\Pi_i^s(c)$ , which will be a function of the strategic choice  $s$  and indicator  $\iota$  capturing successful innovations and the level of competition, given by  $c$ .<sup>1</sup>

The sequence of events in the model is captured by Figure 1. In stage 0, we assume that firms initially make an irreversible strategy choice of whether to pursue innovation or not; this is captured by the indicator  $s \in \{0,1\}$ , which is 1 if they pursue innovation.

If firms do not pursue innovation ( $s = 0$ ), the expected profit will not depend on innovation outcomes and will simply be given by  $\Pi^0(c)$  in stage 2. We will call such firms “non-innovators.” On the other hand, if firms do pursue an innovation strategy ( $s = 1$ ), then their profits will ultimately depend on whether innovations are successful. We use  $\iota \in \{0,1\}$  as the indicator for a successful innovation and  $p = Prob\{\iota = 1\}$  as the probability of successful innovation. In stage 1, firms that pursue an innovation strategy can increase their chances of successful innovations by investing in R&D, with a cost function given by  $R(p) = \frac{1}{2}\kappa \cdot p^2$ . After these investments, the probabilistic innovation outcome is realized in stage 2, at which point there will be successful innovators ( $\iota = 1$ ) as well as failed innovators ( $\iota = 0$ ). Regarding profits, we define  $\pi_\iota(z) = \frac{z_\iota}{c}$  as the post-innovation profits, which depend on the level of competition  $c$  as well as the post-innovation firm level productivity index  $z_\iota$ . After innovations are realized, firms will be heterogeneous, depending on the productivity  $z_\iota$ , and will only continue operating if they can cover overhead fixed costs

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<sup>1</sup> Higher values of  $c$  denote more competition. For example, in a standard trade model with CES preferences, elasticity of substitution  $\eta$ , and  $P$  as the CES price index, competition would be captured by  $c = P^{-(\eta-1)}$ .

$$\pi_t(z) \geq f \tag{1}$$

We use a specific example of the model to facilitate the analysis:

- If innovations are successful, firms are assumed to generate a productivity  $z_1$  that is sufficiently high for them not to exit (i.e.  $\delta_1 = 0$ ).
- Similarly, we assume that exit probabilities for non-innovators ( $s=0$ ) are constant and their productivity is given by  $\bar{z}$ .
- Failed innovators realize a productivity  $z_0 \in [\underline{z}, \bar{z}]$  with  $\underline{z} < \bar{z}$ . We assume these productivity draws are continuously distributed with cdf  $G(\cdot)$ . Together with the previous assumption, we therefore assume that failed innovators' productivity is typically lower than non-innovators. This assumption captures the idea that failed innovation lead to significant costs, such as delayed implementation on other projects and shutdown costs of innovation projects. On a technical level, this assumption is needed to introduce endogenous selection in the simplest, yet most appealing way.

Exit for failed innovators is determined by whether productivity is above a cutoff that is influenced by competition. If  $z_0 < z^c(c)$ , then failed innovators exit.

In general, for innovation strategy firms, the expected profit, conditional on innovation, is given by:

$$\Pi_t^1(c) = (1 - \delta_t(c)) \cdot \psi_t(c) \tag{2}$$

with  $(1 - \delta_t(c)) = P(\pi_t(z) \geq f)$  as the survival probability and  $\psi_t(c) = E[\pi_t(z) - f | \pi_t(z) \geq f]$  as the profits, conditional on survival.

As a result, the optimal investment problem for innovation strategy firms at stage 1 is:

$$p(c) = \arg \max_p \Pi^1(p, c) = p \cdot \Pi_1^1(c) + (1 - p) \cdot \Pi_0^1(c) - \frac{1}{2} \kappa \cdot p^2 \quad (3)$$

Anticipating the degree of competition and optimal investment choices, the optimal strategy choice is given by

$$s(c) = \arg \max_{s \in \{0,1\}} \{ \Pi^{1-s}(c) - F_X, \quad (4)$$

$$\Pi^s(p(c), c) = p(c) \cdot \Pi_1^1(c) + (1 - p(c)) \cdot \Pi_0^1(c) - \frac{1}{2} \kappa \cdot p(c)^2 \}$$

where  $F_X$  formalizes an adjustment costs that makes changing from an innovation strategy to a non-innovation strategy costly. This framework now enables us to analyze the impact of competitive shocks, such as increased international competition from China, on optimal choices as well as performance. In addition to the strategy choice, the model also allows us to parsimoniously differentiate between product and process innovations, which is important to understand the data.

## A.2 Optimal responses to competition

The key feature of the model that allows us to differentiate between process and product innovations can be formalized when looking at the optimal innovation investment decision  $p(c)$  and its response to changes in competition:

$$p'(c) = \frac{1}{\kappa} \left( \frac{d\Pi_1^1(c)}{dc} - \frac{d\Pi_0^1(c)}{dc} \right) = \frac{\xi(c)}{\kappa} \quad (5)$$

where we defined  $\xi(c) = \left( \frac{d\Pi_1^1(c)}{dc} - \frac{d\Pi_0^1(c)}{dc} \right)$  as the differential marginal impact of competition on profit for successful versus failed innovators. Based on  $\xi(c)$ , one can differentiate two cases.

Case 1: Process innovation:  $\xi(c) = \left( \frac{d\Pi_1^1(c)}{dc} - \frac{d\Pi_0^1(c)}{dc} \right) < 0$ .

In this case, an increase in competition will lead to a fall in innovation investments, driven by the fact that more competition reduces anticipated profits. In our model, we think of process innovations as increasing firm productivity so that  $z_1 > z_0$ . Since  $\Pi_t^1(c) = \frac{z_t}{c}$ , this case follows immediately from the model.

Case 2: Product innovation:  $\xi(c) = \left( \frac{d\Pi_1^1(c)}{dc} - \frac{d\Pi_0^1(c)}{dc} \right) > 0$ .

In this case, an increase in competition will have the opposite effect from before and will increase innovation incentives. This will be the case in any model in which successful innovators' profits are less impacted by competition than failed innovators' profits. Previous models such as Aghion, Bloom, Blundell, Griffith, and Van Reenen (2005) exhibited this feature only for "frontier innovations." To simplify our analysis, we will assume that successful product innovations will completely shield successful innovators' profits from the effects of increased competition. Together these results imply:

***Hypothesis 2:*** *If innovation investments are reversible, the number of successful innovations responds to large competitive shocks. The number of process innovations should fall in response*

to competition, while the number of product innovations should rise or at fall less in response to competition.

Given the distinction between product and process innovations, we can now discuss the implications of competitive shocks on initial strategy choice. Note that firms will choose to pursue an innovation strategy according to (4) if  $\Pi^1(p(c), c) - \Pi^0(c) + F_X \geq 0$ . In other words, the greater the difference between profits of an innovation strategy and the profits of being a non-innovator, the more likely firms will choose an innovation strategy. The impact of a competitive shock on initial strategy choice can therefore be summarized by

$$\begin{aligned} \frac{d\Pi^1(p(c), c)}{dc} - \frac{d\Pi^0(c)}{dc} &= \left( \frac{d\Pi_0^1(c)}{dc} - \frac{d\Pi^0(c)}{dc} \right) \\ &+ \left( \frac{1}{\kappa} \right) (\Pi_1^1(c) - \Pi_0^1(c)) \cdot \xi(c) \end{aligned} \quad (6)$$

where a positive value will imply that innovation strategies are more likely to be chosen, while negative values will imply that firms will be more likely to choose non-innovation as a strategy in response to competition. However, since the condition for actually optimally changing strategy also depends on the adjustment cost  $F_X$ , firms might optimally decide not to change their strategy.

This directly implies:

**Hypothesis 1:** *If innovation strategies are costly-to-reverse, innovation strategy choices will be unresponsive to competitive shocks, even if these competitive shocks are salient to managers. Firms that respond earlier to competitive shocks by changing their innovation strategy choice are not necessarily performing better.*

A key insight from explicitly modeling the innovation strategy choice is that information from optimal innovation investment by itself is not sufficient to understand how competition shapes initial strategy choices. This can be seen in (6) by recognizing that the strategy choice does not just depend on the sign of the term  $\xi(c)$ , which was sufficient to understand innovation investments. Intuitively, we need to know more than how competition differentially impacts the profits of successful and failed innovators. We also need to understand how competition affects the profit difference between non-innovators and failed innovators, as captured in the first term of the right-hand side of (6). This term is typically positive in our model, as we assume that failed innovators have a lower productivity than non-innovators:  $z_0(\omega) < \bar{z}$ .









Innovation investments	Process innovations	Product innovations
$R'(c) \propto p'(c) \propto \frac{d\Pi_1^1(c)}{dc} - \frac{d\Pi_0^1(c)}{dc}$		
(Business) strategy choice $\frac{d[E[\Pi^1] - R(p) - \Pi^0]}{dc}$		
Exit $\frac{d[\delta^1(c) - \delta^0]}{dc}$		
Performance, conditional on survival $\frac{d[E[\ln \psi^1] - \ln \psi^0]}{dc}$		

Table 1: Theoretical predictions of risky innovation model with endogenous exit. The superscript  $s = 1$  denotes firms with an initial innovation strategy, while firms with an  $s = 0$  superscript denote non-innovators. The first two rows capture unconditional moment predictions, while the last two columns capture performance predictions conditional on strategy choice.

The overall impact of the strategy choice will then depend on the sum of the positive first term in equation (6) and the second term, which differs for product versus process innovation. While the impact of competition makes innovation strategies unambiguously more likely in the case of



product innovations, the same is not true in the case of process innovations. Competition drives profits from choosing a process innovation strategy in two directions. On the one hand, there is an incentive towards adopting a process innovation strategy, driven by the fact that non-innovators may suffer higher profit losses from competition than failed innovators (first term). On the other hand, successful innovation becomes less likely as firms optimally reduce innovation efforts (second term).

### **2.3 Performance impact of competition, conditional on strategy**

The previous section discussed optimal innovation investment and strategy choices. In this section, we focus on performance, conditional on an initial strategy choice, since the firm strategy data is an important and novel feature of our empirical analysis. Our theoretical considerations highlight that the strategy data allow us to contrast the differential performance responses of average innovators – including successful and failed innovators – with the performance responses of non-innovators. The theory also shows that we should expect different performance impacts of competition, depending on whether the innovation strategy under consideration is related to process versus product innovations. Finally, we note that these conditional performance predictions can be considered robust with respect to our maintained assumption that initial strategy choices are optimal.

We start out with firm exit. We show in the appendix that the difference in exit rates between innovators and non-innovators is given by

$$\frac{d(\delta^1(c) - \delta^0(c))}{dc} = (1 - p(c)) \cdot (\delta_0^{1'}(c)) + \frac{\xi(c)}{\kappa} \cdot (\delta_1^1 - \delta_0^1(c)) \quad (7)$$

where  $\delta^s$  is the exit rate, conditional on strategy  $s \in \{0,1\}$ , and  $\delta_1^1 > 0$  is the exogenous exit rate for successful innovators, while  $\delta_0^1(c)$  is the endogenous exit rate for failed innovators based on selection equation (1). The first term of (7) will typically be positive, as the chance of failed innovation is positive and increased competition will increase exit rates of failed innovators. As before, the impact of competition on exit rates for firms with different strategies depends in part on the difference between product and process innovations, as captured by the sign of  $\xi(c)$ , as we assume that exit rates for failed innovators are higher than for successful innovators:  $\delta_1^1 - \delta_0^1(c) < 0$ .

For the case of process innovations,  $\xi(c) < 0$ , (7) will be positive, so that more competition will unambiguously raise exit rates of firms with innovation strategies relative to non-innovators. In the opposite case of product innovations,  $\xi(c) > 0$ , the impact of innovation on exit rates of innovation strategy firms relative to non-innovators is ambiguous, as an increase in innovation investments in response to competition will lead to more successful innovators, an effect that is countered by increased endogenous exit, which is the first term in (7). The surprising implication is that even if empirically exit rates do not significantly change in response to increased competition, product innovation strategies should still be considered risky, as the likelihood of bankruptcy increases. But this increase in firm exit is hidden in the case of product innovation strategies, as innovation investments increase.

While the predicted response of exit to competition is unambiguous for process innovation strategies and ambiguous for product innovation strategies, the reverse is true for the predictions

of profits conditional on survival. As shown in the appendix, for the case of process innovation strategy, the difference in profit responses to competition between firms that pursue innovation strategy and those that do not is given by

$$d \ln \Pi^1(c) - d \ln \Pi^0(c) = \frac{\xi(c)}{\kappa} \cdot (\ln \psi_1^1 - \ln \psi_0^1(c)) + (1 - p(c)) \cdot d \ln \psi_0^1(c) \quad (8a)$$

This term has an ambiguous sign for the process innovation strategy case of  $\xi(c) < 0$ . The first term is negative and captures the fact that firms with a process innovation strategy reduce their innovation investments, which leads to more failed innovators with low productivity. This is partially countered by the second effect, which captures the selection effect of more competition forcing out the lowest-productivity firms so that productivity conditional on survival is higher.

Together, we have derived:

**Hypothesis 3A:** *More competition increases exit rates of firms pursuing process-innovation strategies relative to non-innovators, but might have an ambiguous effect on average profits of surviving process-innovation strategy compared to surviving non-innovators.*

While the profit predictions for firms pursuing a process innovation strategy are ambiguous, they are unambiguous for the case of product innovation strategy. In that case, the differential profit effect between innovators and non-innovators is given by

$$d \ln \Pi^1(c) - d \ln \Pi^0(c) = \frac{\xi(c)}{\kappa} \cdot (\ln \psi_1^1 - \ln \psi_0^1(c) + \ln c) + (1 - p(c)) \cdot d \ln \psi_0^1(c) + p(c) \cdot \frac{1}{c} \quad (8b)$$

In this case,  $\xi(c) > 0$ , and both the innovation investment effect and the selection effect tend to increase profits, conditional on survival. Combined with the exit rate results from above, we have derived:

***Hypothesis 3B:*** *More competition can have an ambiguous effect on exit rates of product-innovators relative to non-innovators, but will have a positive effect on average profits of surviving product-innovators compared to surviving non-innovators.*

## **Appendix B: Supplemental cross-sectional facts on innovation strategy choices from the Survey of Innovation and Business Strategy (SIBS)**

Since the amount of disclosure of industry-level summary statistics for the WES is restricted by Statistics Canada and the WES ends in 2006, we also analyzed industry-level data from the related Survey of Innovation and Business Strategy (SIBS) for the year 2009. This survey is only a repeated cross-section and is therefore not useful for our main analysis of within-firm responses to the China shock. But its industry level data are still comparable and it includes other questions related to innovation that provide useful context and summary statistics. In particular, the SIBS industry level summary statistics displayed in table B show that a relatively large fraction of firms (almost half) successfully innovate over a three year period.

Table B: Industry-level Summary Statistics (SIBS 3/4-digit NAICS aggregation)

NAICS	Category Name	Chinese import share		Innovation outcomes (share of firms)		Innovation strategies (share of firms)	
		Change 1999-2005	1999	Product	Process	Product	Process
3341	Computer and peripheral equipment manufacturing	0.275	0.036	0.653	0.386	0.5	0.534
3333	Ventilation, heating, air-conditioning, and commercial refrigeration	0.266	0.073	0.691	0.521	0.547	0.513
3152	Cut and sew clothing manufacturing	0.248	0.216	0.306	0.125	0.212	0.208
337	Furniture and related product manufacturing	0.208	0.088	0.378	0.44	0.429	0.407
334R	Computer and electronic product manufacturing	0.182	0.088	0.488	0.503	0.321	0.901
315R	Clothing manufacturing	0.181	0.286	0.553	0.481	0.375	0.286
3342	Communications equipment manufacturing	0.167	0.041	0.676	0.342	0.696	0.595
339R	Miscellaneous manufacturing	0.154	0.201	0.445	0.537	0.373	0.518
314	Textile product mills	0.151	0.087	0.404	0.444	0.343	0.332
3352	Household appliance manufacturing	0.144	0.098	0.726	0.636	0.725	0.543
3351	Electric lighting equipment manufacturing	0.142	0.231	0.748	0.583	0.656	0.245
316	Leather and allied product manufacturing	0.129	0.301	0.617	0.452	0.447	0.339
3219	Other wood product manufacturing	0.113	0.060	0.382	0.53	0.201	0.359
3117	Seafood product preparation and packaging	0.104	0.023	0.098	0.358	0.195	0.346
3323	Architectural and structural metals manufacturing	0.095	0.014	0.306	0.445	0.21	0.432
327	Non-metallic mineral product manufacturing	0.083	0.057	0.376	0.468	0.26	0.419
3344	Semiconductor and other electronic component manufacturing	0.083	0.018	0.589	0.589	0.496	0.47
3212	Veneer, plywood and engineered wood product manufacturing	0.083	0.005	0.256	0.496	0.341	0.353
3211	Sawmills and wood preservation	0.079	0.007	0.316	0.5	0.282	0.322
332X	Other fabricated metal product manufacturing	0.076	0.036	0.417	0.522	0.346	0.557
331R	Primary metal manufacturing	0.074	0.038	0.387	0.602	0.234	0.447
3359	Other electrical equipment and component manufacturing	0.065	0.026	0.527	0.574	0.465	0.547
3334	Metalworking machinery manufacturing	0.064	0.008	0.525	0.696	0.273	0.525
3391	Medical equipment and supplies manufacturing	0.063	0.034	0.701	0.64	0.49	0.512
3324	Boiler, tank and shipping container manufacturing	0.051	0.011	0.422	0.517	0.422	0.573
326R	Plastics and rubber products manufacturing	0.049	0.043	0.599	0.597	0.459	0.451
3369	Other transportation equipment manufacturing	0.047	0.072	0.438	0.5	0.438	0.625
313	Textile mills	0.046	0.045	0.553	0.603	0.483	0.396
323	Printing and related support activities	0.046	0.024	0.291	0.521	0.34	0.462
3122	Tobacco manufacturing	0.045	0.001	NA	NA	NA	NA
3262	Rubber product manufacturing	0.045	0.014	0.422	0.532	0.495	0.656
3313	Alumina and aluminum production and processing	0.042	0.003	0.366	0.59	0.229	0.321
331X	Other metal production and processing	0.040	0.010	0.461	0.522	0.269	0.328
3345	Navigational, measuring, medical and control instruments	0.039	0.020	0.622	0.527	0.572	0.523
3327	Machine shops, turned product, and screw, nut and bolt	0.037	0.012	0.192	0.605	0.214	0.406
3353	Electrical equipment manufacturing	0.036	0.018	0.474	0.514	0.439	0.508
3222	Converted paper product manufacturing	0.036	0.028	0.315	0.547	0.333	0.425
333R	Machinery manufacturing	0.027	0.006	0.568	0.485	0.529	0.479
3114	Fruit and vegetable preserving and specialty food manufacturing	0.026	0.022	0.513	0.512	0.245	0.584
3363	Motor vehicle parts manufacturing	0.018	0.007	0.393	0.599	0.397	0.491
325X	Other chemical product manufacturing	0.013	0.004	0.472	0.521	0.402	0.435
3365	Railroad rolling stock manufacturing	0.013	0.002	0.545	0.455	0.364	0.273
3111	Animal food manufacturing	0.009	0.008	0.429	0.434	0.315	0.533
3251	Basic chemical manufacturing	0.008	0.013	0.432	0.414	0.296	0.402
3221	Pulp, paper and paperboard mills	0.007	0.001	0.441	0.33	0.26	0.356
3252	Resin, synthetic rubber, and artificial and synthetic fibres and filaments	0.005	0.001	0.47	0.669	0.536	0.64
311R	Food manufacturing	0.005	0.013	0.519	0.635	0.254	0.584
3118	Bakeries and tortilla manufacturing	0.004	0.008	0.353	0.348	0.42	0.334
324	Petroleum and coal product manufacturing	0.004	0.001	0.501	0.269	0.27	0.462
3116	Meat product manufacturing	0.002	0.001	0.297	0.407	0.187	0.307
3255	Paint, coating and adhesive manufacturing	0.002	0.001	0.579	0.421	0.594	0.488
3364	Aerospace product and parts manufacturing	0.002	0.001	0.484	0.611	0.413	0.608
3362	Motor vehicle body and trailer manufacturing	0.002	0.001	0.479	0.415	0.344	0.364
3254	Pharmaceutical and medicine manufacturing	0.001	0.007	0.59	0.503	0.521	0.503
3361	Motor vehicle manufacturing	0.000	0.000	0.444	0.722	0.333	0.611
3121	Beverage manufacturing	0.000	0.001	0.581	0.559	0.114	0.348
3115	Dairy product manufacturing	0.000	0.003	0.448	0.494	0.331	0.48
3366	Ship and boat building	-0.001	0.006	0.435	0.406	0.163	0.324
3328	Coating, engraving, heat treating and allied activities	NA	NA	0.151	0.388	0.122	0.245
	Unweighted mean across industries	0.068	0.043	0.463	0.501	0.371	0.452
	Unweighted median across industries	0.045	0.014	0.455	0.513	0.345	0.457
	Correlation with change in Chinese import share		0.635	0.175	-0.236	0.231	-0.029
	Correlation (Innovation outcome, strategy)			0.702	0.395		
	Correlation between different innovation outcomes/strategies				0.262		0.363

Notes: We report trade flows and innovation measures using the 3/4-digit NAICS aggregation (59 industries) from the 2009 Survey of Innovation and Business Strategy (SIBS) public-release data. Innovation outcomes are self-reported by firms as introducing "New or significantly improved goods" or "New or significantly improved method of manufacturing or production" over the last 3 years. Innovation strategies are self-reported by firms as "Introduce new or significantly improved goods or services regularly" and "Introduce new or significantly improved business activities or processes to its operations for the long term" in response to questions about the strategic focus of the enterprise with respect to its "goods or services" or "operations or business activities." The omitted categories for strategies are "maintain or expand the sales of existing goods or services" and "maintain or optimize current operations and business activities for the long term".

Innovation strategies in the SIBS (defined less stringently than in table 1 of the paper, see table notes) are also quite common, and table B shows that the high share of manufacturing firms with innovation strategies and outcomes is broad-based and not driven by a few industries. Industries in which more firms adopt innovation strategies have a higher share of firms with successful

innovation outcomes but the correlation is well below one. The share of firms with an innovation strategy is sometimes above and sometimes below the share of firms with a successful innovation outcome in an industry. This indicates that innovation strategy may be an important predictor of successful innovation outcomes but is neither a necessary nor a sufficient condition. The use this data and its less stringent strategy definition in our supplemental long-run analysis of innovation strategy choices in section 5.4 of the main paper.