

Table 2. Result summary of matched pre and post treatment means of metrics and standard errors along with overall calculated difference.

		Pre treatment mean (SE)	Post treatment mean (SE)	DiD
Orangutan (Number of individuals)	RSPO certified	18 (6.4)	12.3 (4.6)	1.2
	Non-certified	22.6 (7.3)	18.1 (5.1)	
Fire (Number of incidents)	RSPO certified	2	6.69 (1.81)	0.303
	Non-certified	2	6.38 (1.64)	
Health facilities (Number of facilities)	RSPO certified	1.14 (0.11)	0.897 (0.09)	−0.0636
	Non-certified	1.41 (0.09)	0.807 (0.07)	
Reduced No. poverty letters (Number of households)	RSPO certified	13.3 (1.46)	48.1 (9.50)	−16.506
	Non-certified	17.5 (4.09)	68.8 (9.65)	
Yield (Fresh fruit bunch mT)	RSPO certified	1 479 000 (736 965)	7 922 984 (2 229 848)	6 057 117
	Non-certified	403 036 (25 621)	789 900 (60 099)	
Profit (Share value SGD)	RSPO certified	0.912 (0.66)	2.99 (1.23)	1.12
	Non-certified	1.15 (0.60)	2.10 (1.27)	

Social

Poverty

Certification did not reduce poverty, but was associated with a reduction in the rate of increase. The proportion of families receiving SKTM poverty letters has increased over time in villages neighbouring both certified and non-certified concessions. Although a similar number of families held SKTM letters prior to certification across treatment types, more SKTM letters were held by families neighbouring non-RSPO concessions than RSPO concessions post certification (figure 3(a), table 2). Supplementary analysis where concessions were matched on the initial number of SKTM letters, revealed a similar trend (S3.2).

Healthcare

Certification did not increase access to healthcare, but was associated with a reduced decline. The number of health care facilities per capita has declined between 2000–2014. Although villages neighbouring non-RSPO concessions had slightly more health facilities per capita than RSPO concessions prior to certification, the number of facilities across treatment types post certification are more similar (figure 3(b), table 2).

Economic

Profit

Certification was associated with a greater increase in profit. Share prices of RSPO and Non-RSPO concessions have increased in value between 2005–2016, increasing by 2.08 and 0.095 SGD respectively. Although having a similar value pre-certification, RSPO concessions share prices were valued slightly higher than Non-RSPO concessions post certification (figure 3(a), table 2).

Yields

Certification was associated with an increase in improved yield. Fresh Fruit Bunch yields from non-certified estates showed consistent production whereas RSPO estates displayed increasing yields over time. Although differences between treatment types are not statistically significant, RSPO estates with similar ages crops were producing 5 t of Fresh Fruit Bunches per hectare of planted area more than non-certified estates,

equating to almost 3 times (4 000 000 metric tonnes) more FFB at an estate level than non-RSPO concessions (figure 3(b), table 2). Supplementary analysis revealed that when matched on levels of initial FFB outputs, RSPO concessions showed a significant increase in production levels (S3.3).

Discussion

Our analysis shows that RSPO certification has resulted in better outcomes for economic sustainability than business as usual from an industry perspective. Environmental and social benefits, however, are less clear. The palm oil industry continues to be criticised for its adverse environmental and social impacts (Fitzherbert *et al* 2008, Wilcove and Koh 2010, Wicke *et al* 2011, Abram *et al* 2017). Indeed, our results suggest that low confidence in the mechanisms for improving overall industry sustainability appears warranted in all but very narrow and economically-oriented interpretations of sustainability.

Environmental sustainability

No evidence was found to suggest that RSPO certified plantations were able to retain populations of orangutan better than non-certified concessions. RSPO concessions were also found to have fewer individuals per concession before certification ($\mu = 18$) than comparably sized non-certified concessions ($\mu = 22$). The difference in baseline orangutan population numbers likely reflects patterns of land use and clearing. As RSPO regulations prohibit new plantations from replacing primary forest from November 2005 (RSPO P&C 7.3), forested land and viable orangutan habitat would likely have been cleared in the years prior to certification for current and potential future plantation establishment. Conversely, as no clearing regulations exist for non-certified plantations: many still contain forest patches and viable habitat, particularly concessions that have been gazetted but are at present inactive Meijaard *et al* (2017).

The number of fire hotspots detected within palm oil concessions increased equally in both RSPO and non-RSPO concessions between 1999–2004 and