This paper proposes the output feedback control schemes for underactuated spacecraft hovering without either the radial or the in-track thrust. In contrast to the conventional fully actuated output feedback hovering control that only lacks velocity signals, a new problem is observed in the underactuated case that the simultaneous loss of velocity measurements and thrust does not only result in the loss of velocity information but also gives rise to unknown system parameters' effects. Furthermore, due to the loss of thrust, the disturbances turn into unmatched ones. To achieve velocity-free hovering control for the underactuated cases, a novel adaptive reduced-order observer is first proposed for the purpose of velocity and parameter estimation. With the estimates provided by the observer, an output feedback controller is then designed by using the inherent coupling of system states. The asymptotic stability of the overall closed-loop system for either case is guaranteed by a Lyapunov-based method. Finally, numerical simulations are presented to demonstrate the feasibility and validity of the proposed controllers for hovering perturbed by the unmatched disturbances with the simultaneous loss of velocity measurements and thrust.